PNNL-12249

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Report to the Nuclear Energy Research Advisory Committee (NERAC) Subcommittee on "LongTerm Isotope Research and Production plan7'-- Responses to Questions

July 1999

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL01830

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July 1999

Information provided to the Nuclear Energy Research Advisory Committee's subcommittee on the development of a "Long-Term Isotope Research and Production Plan"

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Introduction

This report presents responses to two series of questions that were raised by a subcommittee of the Nuclear Energy Research Advisory Committee (NERAC) that has been charged with producing a "Long-Term Isotope Research and Production Plan." The NERAC subcommittee is chaired by Dr. Richard Reba, and the Hanford Site Visit team, which comprises a subset of the subcommittee members, is chaired by Dr. Thomas Ruth.

The first set of questions raised by the subcommittee on isotope production at the Hanford Site was received from Dr. Ruth on May 10, 1999, and the second set was received from him on July 5, 1999. Responses to the first set of questions were prepared as part of a June 1999 report entitled "Isotope Production at the Hanford Site in Richland, Washington" (PNNL 1999a). The responses to these questions are summarized in this document, with frequent references to the June 1999 report for additional details. Responses to the second set of questions from the NERAC subcommittee are presented in this document for the first time.

1 Responses to the First Set of Questions

The set of questions received on May 10, 1999, consisted of two broad questions, the first of which contained 10 individual questions to which responses are given below.

1.0 How well does the Department's existing five-site production infrastructure serve the need for commercial and research isotopes?

1.1 What is the physical condition of the isotope processing facilities and equipment?

Response:

The primary isotope production facilities at the Hanford Site are the Radiochemical Processing Laboratory (RPL) (Building 325 in the 300 Area of the Hanford Site) and the Fast Flux Test Facility (FFTF) reactor (in the 400 Area of the Hanford Site). In addition, there are several other laboratory facilities that are suitable for various aspects of target preparation and radiochemical processing of isotopes. These facilities are discussed briefly in this document, with reference to PNNL (1999a) for additional details.

(a) **RPL.** The RPL is a 143,700 ft^2 building that contains laboratories and specialized facilities designed for work with nonradioactive materials, microgram-to-kilogram quantities of fissionable materials, and up to megacurie quantities of other radionuclides. The total space occupied by general chemistry laboratories is 44,300 ft^2, of which 6,950 ft^2 (15.6%) is presently unoccupied. All of the occupied, and nearly all of the unoccupied laboratories are functional and fully equipped with standard utilities. Several of the laboratories, especially those used for radioanalytical work, have been renovated during the past few years. The upgrading and modernization of equipment within the chemistry laboratories has been given a high priority during the past two years.

During a recent space utilization survey of the RPL, an assessment was made of the number of fume hoods and shielded glove boxes (including small hot cells) that are available for additional programmatic work. Of the 79 functional fume hoods and 23 shielded glove boxes, 50 and 15, respectively, are available for additional work.

A special feature of the RPL is the existence of two heavily shielded facilities located in annexes on the East and West sides of the building. These shielded facilities are the High-Level Radiochemistry Facility (HLRF) and the Shielded Analytical Laboratory (SAL). These two hot cell complexes, which are heavily utilized at the present time, provide capabilities for conducting bench-scale to pilot-scale work with a wide variety of highly radioactive materials. Capabilities include those required to conduct radiochemical separation and purification procedures, irradiated fuel or target sectioning and processing, metallography, physical properties testing of activated metals, thermal processing (including waste vitrification), and radioanalytical and preparatory chemistry operations.

The HLRF contains three large, interconnected hot cells designated as A-Cell, B-Cell, and C-Cell. The three cells are each 15 ft high and 7 ft deep; the A-Cell is 15 ft wide and the B-Cell and C-Cell are each 6 ft wide. In-cell operations are performed using medium-duty electromechanical manipulators, and the work is viewed through leaded-glass, oil-filled windows. The hot cells are equipped with television cameras, VCRs, overhead bridges, hoists, and standard utilities. They have shielded service penetrations at the front wall for insertion of special instrumentation.

The SAL contains six interconnecting hot cells, each of which is 5.5 ft wide, 5.5 ft deep, and 9.5 ft high. Each hot cell is equipped with a pair of medium-duty manipulators. Turntables built into the rear walls of the hot cells provide rapid transfers of radioactive samples into and out of the cells. The SAL hot cells are equipped to perform a wide variety of analytical chemistry operations with highly radioactive samples.

Additional information on the RPL, and its laboratory facilities that could be devoted to new isotope production missions in the future, is contained in PNNL (1999a) (Section 2.5.1).

(b) **FFTF.** The FFTF's original mission was to support liquid-metal reactor technology development and reactor safety by providing fuels and materials irradiation services. Although the U.S. liquid-metal reactor program ended at about the same time that the FFTF commenced operation in 1982, the reactor continued operation for 10 years as a national research facility to test advanced nuclear fuels and materials, nuclear power plant operating procedures, and active and passive reactor safety technologies. The facility was also used to produce more than 40 different radioisotopes for use in research, medicine, and industry. In addition, FFTF generated tritium for the U.S. fusion research program and supported cooperative, international nuclear research activities. The reactor was shut down in December 1993, and since that time has been in a standby operational condition, pending a decision by DOE on its future use. In May 1999, the Secretary of Energy announced that a special 90-day study led by the Director of the Pacific Northwest National Laboratory, Dr. William Madia, would be conducted to establish whether the FFTF should be considered for future missions related to national and international nuclear technology needs. The nuclear science and irradiation services provided by FFTF will focus on a core federal role of meeting multiple 21st Century needs, including:

1. providing a large and reliable supply of radioisotopes for research, medical, and industrial applications

2. promoting safer nuclear technology through reactor safety testing and the development of proliferation-resistant nuclear fuels

3. producing power sources for deep-space exploration through the production of plutonium-238 for radioisotope thermoelectric generators, and for research on compact space reactor technology

4. sustaining the nuclear option for power production through testing of fuels, components, and reactor instrumentation

5. conducting advanced research and providing services related to the testing of materials for fusion reactors, hardening and testing of materials such as semiconductors, and research on transmutation of nuclear waste materials.

These future missions, and the business plan for FFTF's proposed future operations, are described in a document that will be submitted to NERAC on July 20, 1999 for review before submission to the Secretary of Energy on August 2, 1999. This document is entitled "Program Scoping Plan for the Fast Flux Test Facility: A Nuclear Science and Irradiation Services User Facility"(PNNL 1999b).[a]

The FFTF consists of the reactor, which is capable of steady-state operation at a rated power level of 400 MW, and several support buildings and equipment arranged around the central reactor containment building. Heat is removed from the reactor by liquid sodium that is circulated through three primary loops, which include the pumps, piping, and intermediate heat exchangers. During a total loss of power, the FFTF is designed to shut down automatically and the reactor will continue to be cooled by natural circulation of the sodium. An emergency power source consisting of batteries will provide essential plant monitoring capabilities in the event of a shutdown. The reactor also has safety features that can maintain cooling if a leak occurs in the liquid sodium heat transport system.

Other major systems located in the FFTF reactor containment building are:

- the Closed Loop Ex-Vessel Handling Machine that is used to install fuel and target assemblies in the reactor and to remove them at the end of the irradiation cycle

- the Interim Examination and Maintenance (IEM) Cell, in which an irradiated assembly is washed and dried to remove residual sodium before disassembly; the target pins are then removed from irradiated assemblies with manipulators and placed in containers for removal from the IEM cell

- a Bottom-Loading Transfer Cask, which is used to transfer the pin container from the reactor containment building to a cask loading station in the Reactor Service Building.

Detailed descriptions and photographs of the FFTF containment building and the special facilities described above are contained in PNNL (1999a) (Section 2.5.2).

(c) **Other Available Facilities.** In planning for a proposed future FFTF isotope production mission, several facilities at the Hanford Site have been examined as possible locations for target preparation and the processing of isotope products. In all cases, these facilities have desirable physical features and equipment that could make them useful if an expansion of facilities is required later to meet a growth in the demand for FFTF isotope products. Three candidate facilities are:

(a) This document is referred to hereafter in this report as the "FFTF Scoping Plan."

1. *Building 306E.* Located in the 300 Area of the Hanford Site, this facility has been used in the past to fabricate a variety of reactor components, fuel assemblies, and radioisotope target assemblies. Some of the target fabrication equipment and non-destructive examination equipment still exist in the building and are available for use.

2. *Postirradiation Testing Laboratory.* Located in the 300 Area at the Hanford Site, this facility contains 13 hot cells and support laboratories for the physical and metallurgical examination of irradiated fuels, fission products, and irradiated structural materials. Decontamination of the hot cell facilities has been underway for two years, and is expected to be completed within the next two years. Only a small amount of programmatic work is currently being conducted, and a study on the long-range utilization of this facility is underway, including use by commercial companies under lease agreements. This alternative may be attractive for establishing long-term business relationships with companies interested in the preparation and processing of targets irradiated at FFTF.

3. *Maintenance and Storage Facility.* Located in the 400 Area of the Hanford Site about 500 ft north of FFTF, this facility is a multi-purpose service center that supports the specialized maintenance and storage requirements of the FFTF. A special feature of this facility is a large shielded enclosure that contains two shielded decontamination rooms that can be used for both remote and hands-on cleaning of equipment and tools. This facility, including the shielded enclosures, was not fully utilized during the ten years of full-scale FFTF operation, and consideration has been given to its possible use for the fabrication and disassembly of FFTF targets.

Additional details on each of these facilities are contained in PNNL (1999a) (Section 2.5.3).

1.2 What capital investments are needed to ensure the near-term operability of the facilities? If additional resources are needed, are they practical (e.g., technically rational, easily integrated into existing infrastructure, quickly implemented and supportable)? Will any portion be sustainable over time by local financial and personnel resources?

Response:

As part of the planning activities for a future FFTF nuclear science and irradiation services mission, an estimate has been prepared of the costs associated with restarting the reactor for steady-state operations at a 100-MW power level. This estimate, expressed in FY 1999 dollars, is $229M. The capital expenditures are distributed over a four-year period from 2001 – 2004, and include funds for (1) recovering systems that were shut down before the standby decision in late 1993, (2) equipment and instrumentation upgrades, (3) fabrication of rapid radioisotope retrieval (R3) vehicles for removal of short-lived isotope targets while the reactor is at power, (4) modification of hot cells and support laboratories for target processing operations, and (5) staff increases and training. Once restarted, the estimated annual cost of FFTF operations is $55M. A more detailed description of the schedule and costs for FFTF restart is provided in the FFTF Scoping Plan (PNNL 1999b).

A business model has been developed as part of the FFTF Scoping Plan (PNNL 1999b) that incorporates plans for recovering approximately $100M of the restart costs over the projected 35-year operating life of the reactor. This business model was developed using the guidelines provided in DOE Order 2110.1A, "Pricing of Department Materials and Services and DOE Implementing Guidance on Federal Administrative Charges." The model is comparable to those currently in use at other DOE reactor facilities, and has been reviewed and accepted by the DOE Chief Financial Officer in meetings held during June 1999. The FFTF business model provides adequate resources to ensure both the near-term and sustained future operability of the reactor.

In this business model, the funding in FY 1999 dollars required during the reactor restart phase includes both the $229M discussed above and $55M in operating funds to maintain the FFTF's standby mode of operation during the period 2000-2001. During the projected 35-year operating lifetime of the reactor (2004-2038), a "value recovery charge" of ~4% will be applied to all private-sector irradiation services. The funds recovered through this charge will be placed in an investment fund that is expected to grow at an annual rate estimated to be ~5% above inflation, and thereby generate ~$100M to offset a portion of the restart costs.

The staffing infrastructure to support both the reactor operations and radiochemical processing of irradiated targets are in place and adaptable to rapid growth of the nuclear science and irradiation services components of the FFTF mission. As described in detail in the FFTF Scoping Plan and PNNL (1999a), the operations staff at the FFTF will increase from the current level of 260 full-time equivalent (FTE) to 410 FTE at the time of restart. This increase will accommodate the full set of operational services required for target insertion, irradiation, and retrieval in the isotope production program. Target preparation is expected to be carried out by a subcontractor working in facilities at the Hanford Site.

Radiochemical processing of the isotope targets will be carried out by members of the PNNL Radiochemical Processing Group (RPG), which consists of 75 technical and administrative staff that occupy the RPL (described in PNNL (1999a), Section 2.4.1). The isotope production team within the RPG currently has 12 staff members, of which 5 perform radiochemical processing operations. It is expected that the number of scientists and technicians performing radiochemical operations will increase to 21 FTE at the time FFTF commences full operation. This expansion will be achieved by reassignment of radiochemists and technical support staff within the RPG, and by new hires. In addition to the staff involved in radiochemical processing operations, it is expected that the number of staff involved in packaging and shipping will increase from 0.5 FTE to 7.5 FTE, and that the marketing, sales and administrative staff will increase from 1.5 FTE to 5.5 FTE.

Although the FFTF Scoping Plan (PNNL 1999b) does not explicitly include privatization of the reactor operations or the isotope production mission, discussions have been initiated with private-sector companies that may have an interest in commercializing various components of these operations (e.g., the marketing, sales, and distribution of isotope products). These discussions are expected to continue over the coming five-year period (i.e., during the preparation of the FFTF Environmental Impact Statement and the reactor restart activities), with a reasonable probability of success in establishing partnership agreements between DOE and commercial organizations.

1.3 What is the availability of the primary nuclear facility (accelerator or reactor) over the next five years (e.g., HFIR outage, LANSCE program changes)?

Response:

If the current plans to initiate preparation of an Environmental Impact Statement in October, 1999 are met, then it is expected that FFTF will be restarted by July 2004. Details of the restart schedule are given in the FFTF Scoping Plan (PNNL 1999b). In addition, all of the target preparation and processing facilities such as the RPL are expected to remain available for work in support of the FFTF isotope production mission.

1.4 What understanding exists at each site about the priority of isotope production to serve isotope customers?

Response:

Because many of the isotopes produced at the Hanford Site are shipped to customers at medical centers for the treatment of critically ill cancer patients, the isotope production program receives a very high priority. For example, the staff performing the radioanalytical work and on-site transportation services in support of the isotopes program give this work the highest priority among their multiple tasks. A complete radionuclide analysis and Inductively Coupled Plasma (ICP) analysis of the chemical purity of the isotopes sent to customers are performed within 24 hours of the completion of isotope production. These data are then sent immediately to the customer for review before use of the isotope.

Another example of the high priority given to the medical isotopes program occurred five years ago when the RPL was shut down temporarily for safety upgrades. By direct order of the Manager of the DOE Richland Operations Office, Mr. John Wagoner, the production of yttrium-90 for medical customers was allowed to continue uninterrupted during the entire shutdown period, which lasted about one year.

1.5 How much influence does each site manager have in planning the use of multi-purpose facilities?

Response:

The Manager of the Hanford Radioisotopes Program, Dr. Thomas Tenforde, also serves as the lead scientist for the isotope production team within the RPG. The organizational structure and primary areas of research are described in PNNL (1999a) (Section 2.4.1). In his capacity as head of the isotope production team within the RPG, the manager of the Hanford Radioisotopes Program has line management responsibilities for the staff and facilities involved in the radiochemical processing of isotopes for commercial, medical, and research applications. These staff, together with a matrixed team of nuclear physicists, engineers, radiochemists, and nuclear safety specialists from PNNL and other Hanford contractor organizations, have functioned since 1997 as a support group for planning the proposed future FFTF isotope production mission. An important part of this planning has been the identification of laboratory facilities that will be given a high priority for future use in support of the FFTF isotope production mission.

1.6 What cost-containment measures are being pursued?

Response:

Cost-containment efforts in the isotopes program are centered around the use of activity-based costing procedures for all isotope products. Following the costing procedures adopted by the DOE Office of Isotope Programs (NE-70), an annual cost/price analysis is performed on each isotope product using a four-level Work Breakdown Structure. Examples of this type of cost analysis are given in PNNL (1999a) (Section 2.6.1) and in the response given below to the first of the new set of questions received from the NERAC subcommittee on July 5, 1999.

In all aspects of isotope production, efforts are made to streamline the radiochemical laboratory procedures and to use the most economical services available from various contractor organizations at the Hanford Site. For example, ICP analyses of the chemical purity of isotope products are performed at the 222S Building under a subcontract with the Fluor Daniel Hanford Company, which is a less expensive option (by nearly a factor of 2) than performing these analyses in the RPL operated by PNNL.

1.7 What licensing issues need to be addressed?

Response:

If a decision is made to restart the FFTF, it will be subject to all DOE requirements for the operation of a nuclear facility, as described under DOE Order 425.1A ("Startup and Restart of Nuclear Facilities," 1995). Licensing of the FFTF under the regulations for commercial reactors will not be a regulatory requirement. However, it is expected that DOE will request the Nuclear Regulatory Commission to conduct a detailed technical review of the safety aspects of operating the facility, similar to the procedure that was followed prior to initial startup of the reactor in the early 1980s. In addition, the International Atomic Energy Agency (IAEA) may be requested to verify the inventory and characteristics of nuclear materials at the FFTF. The IAEA has declared its willingness to help facilitate FFTF's use by the international nuclear science community.

It is the goal of the Hanford Radioisotopes Program to transfer technology for the production and applications of medical isotopes to the private sector through appropriate licensing agreements. A recent example is the licensing agreement signed by NEN Life Science Products, Inc., on October 12, 1998, to use PNNL's patented process for extracting yttrium-90 from a strontium-90 generator in a highly purified form. Under this license agreement, the management contractor organization for PNNL — the Battelle Memorial Institute — receives an initial fee of $75K and subsequent royalties based on a percentage of the net sales value of yttrium-90 sold by NEN. The estimated value of this agreement for Battelle is approximately $500K over a five-year license period. This licensing agreement was part of a broader commercialization effort in which NEN took over from PNNL all aspects of the production, marketing, sales, and distribution of yttrium-90 (described in more detail in PNNL (1999a), Section 2.2.2).

Based on the success of the yttrium-90 privatization activity, PNNL is currently involved in efforts to commercialize other technology that has been developed for the medical application of radioisotopes. For example, negotiations are underway with a private company for use of PNNL's radioactive composite polymer delivery system for treating prostate tumors and other forms of cancer.

In addition to technology licensing agreements, consideration has been given to establishing facility lease agreements under which commercial companies could perform work in DOE facilities at the Hanford Site. For example, a study is underway on the feasibility and opportunities for privatizing part or all of the Postirradiation Testing Laboratory described above in the response to Question 1.1. This facility, as well as other laboratories in the 300 Area of the Hanford Site, will be considered for use by private-sector companies in future work related to the preparation and processing of targets for FFTF isotope production.

1.8 What unused or underused capacity (e.g., personnel, facilities) could be mobilized to support a growth in isotope demand?

Response:

As discussed above in the response to Question 1.1, a recent survey of space utilization in the RPL indicated that ~7000 ft^2 of functional laboratory space is currently available for radiochemical work in new projects. It is anticipated that reassignment of laboratory space within the RPL will be made in the future to accommodate the full set of requirements for the radiochemical processing of multiple FFTF isotope targets. In addition, as also discussed above in the response to Question 1.2, there are extensive support facilities available for isotope target preparation and processing in Building 306E and in the Postirradiation Testing Laboratory at the Hanford Site.

With regard to the availability of trained staff who could be mobilized in support of a growth in isotope demand, there are currently about five scientists and technicians within the 75-member RPG that could be utilized in that capacity (in addition to the staff that are members of the isotope production team). The overall workload and availability for new assignments of radiochemistry staff in the RPG is driven primarily by funding for work in support of the Hanford nuclear waste cleanup mission and the processing and disposal of nuclear fuels. As the time approaches for restart of the FFTF reactor in mid-2004, an assessment will be made of staff assignments to support the isotope production mission. It appears likely at this time that recruitment and hiring of new staff will be required during the year preceding restart of the FFTF. However, as indicated above in the response to Question 1.2, ongoing discussions with private-sector companies could lead to privatization of various components of the FFTF isotope production program. The commercialization of various elements of work involved in the preparation, irradiation, and processing of isotope targets, as well as the marketing, sales, and distribution of the final isotope products, could have a significant impact on the staffing requirements that must be met by PNNL and other contractor organizations at the Hanford Site involved in the FFTF isotope production mission.

1.9 Summarize customer inquiries received during the past two years. What percent was filled, referred to other facilities, or rejected? Explain unfilled requests.

Response:

During the past two years the primary isotope product supplied by the Hanford Site has been yttrium-90. Weekly shipments of this medical isotope have been supplied to more than 40 customers who are using yttrium-90 primarily for cancer radioimmunotherapy. As described in PNNL (1999a) (Section 2.6.2), PNNL provided more than 1200 consecutive on-time shipments of yttrium-90 to DOE customers during the two-year period preceding the commercialization of this program. No orders were rejected and there were no unfilled requests for yttrium-90 over the past two years.

Responses are also made to customer inquiries regarding isotopes that are not produced at the Hanford Site. These inquiries are answered within one work day by referring the customers to other DOE Isotope Production Sites or commercial suppliers.

1.10 How does each site manager rate customer satisfaction for his site? For the overall program?

Response:

The level of satisfaction expressed by customers for isotope products supplied by the Hanford Radioisotopes Program has consistently been very high. Our dedication to customer service, as exemplified by the 100% on-time record for more than 1200 shipments of yttrium-90 over the past two years, has earned a number of compliments in letters sent by satisfied customers (summarized in PNNL (1999a), Section 2.6.2). In addition to the timeliness of isotope shipments, the staff involved in isotope production have received a number of compliments for the consistently high quality of isotope products produced at the Hanford Site.

With regard to the overall DOE isotope program, it is our perception that customers are satisfied with the quality of the isotope products that are provided for medical, industrial, and research applications. However, improvements could be made in the availability and timely supply of isotopes that are in demand for therapeutic medical applications and research (e.g., copper-67 and bismuth-212 for early-stage cancer therapy trials and laboratory animal research).

2.0 What should be the long-term role of Government in providing commercial and research isotopes?

Response:

It is our firm belief that the supply of isotopes provided by DOE for medical, industrial, and research applications must be strengthened in the near future. This opinion is reinforced by the conclusions of a recent DOE Expert Panel Report on the future need for medical isotopes (Expert Panel 1999). Many of the radioisotopes currently used for medical diagnosis and therapy of cancer and other diseases are imported from Canada, Europe, and Asia. This situation places the control of isotope availability, quality, and pricing in the hands of non-U.S. suppliers. It is our opinion that the needs of the U.S. customers for isotopes and isotope products are not being adequately served, and that the DOE infrastructure and facilities devoted to the supply of these products must be improved. The need for greater U.S. capabilities to supply isotopes for medicine and research is one of the fundamental bases for our proposal to restart the FFTF as a national DOE resource.

Responses to the Second Set of Questions

The second set of questions received on July 5, 1999, consisted of four questions to which responses are provided below.

1.0 Detail how you set the price of a mCi of a radioisotope. The detail should show if the cost is fully loaded or incremental, and should include labor, materials and parts, facility rental and amortization costs, listing of all actual overhead charges, waste disposal, and all other costs that are tagged to the cost of producing, marketing, selling, and distributing of the product (e.g., customer service, distribution, and ordering). Illustrate the above question with examples for the following radioisotopes: I-131, I-125, Pd-103, P-32, and several research radioisotopes.

Response:

[N.B.: The pages on which the response to the above question is presented are labeled as BUSINESS SENSITIVE to indicate the proprietary nature of the data that are displayed.]

Prices are set by the Department of Energy's Isotope Programs Office (NE-70) using information provided by the Isotope Production Sites in the form of cost/price analyses for all isotope products. The Isotope Production Sites themselves do not set prices for the isotope products produced under the DOE contract. The pricing guidelines used by DOE are described in the annual financial statement, which is audited on a yearly basis by KPMG Peat Marwick. These guidelines state, in brief, that the prices are set on the basis of (1) actual production costs, (2) market value of the product, (3) needs of the research community for the product, and (4) other factors.

In response to the NERAC subcommittee's question, cost/price analyses have been prepared for I-131, I-125, P-32 and Pd-103, as well as several isotopes that are currently in demand for research and early-stage clinical trials. The cost/price analyses were prepared in a format consistent with that used by DOE Isotope Production Sites, and the labor costs are fully burdened. The following are the overhead rates in FY 1999 applied to labor costs by PNNL and the Babcock & Wilcox Hanford Company (BWHC):

- PNNL: G&A + Nuclear Assessment — 44.8%
  Program Development and Marketing — 6.0%
  Service Assessment — 1.0%

- BWHC: Project Management Account — 16.0%
  G&A + Service Assessment — 15.7%

In the cost/price analyses, the labor rates that are used assume that the target preparation, target insertion and retrieval, and irradiation services are performed by BWHC as a subcontractor organization, and the target processing and packaging are performed by PNNL. It is also assumed that PNNL manages the isotopes program office and handles customer sales and service functions.

The following analysis of cost for producing isotopes of interest for research and medical applications is based on several assumptions: (1) the reactor is assumed to be in a steady-state mode of operation, with all equipment and operating procedures in place; (2) the target loading is designed to produce quantities of isotopes per operating cycle that could fill, on the average, about 10 to 20% of the projected U.S. market demand during the period 2005-2010; (3) the irradiation fee for each isotope product is based on the volume of space occupied by the target material in one or more assemblies; (4) all labor costs are fully burdened in accordance with the overhead rates presented above; (5) shipping of the isotope products is FOB Hanford; (6) a 12% added cost multiplier plus a 4% value recovery factor, or 16% total, is applied to the work done by the subcontractor on target fabrication, target testing and qualification, target irradiation, and target insertion and retrieval operations (to recover ~$100M in costs associated with the reactor restart over a 35-year operating period as discussed under the response given above to Question 1.2 in the first set of questions). The cost analyses are performed per target assembly per operating cycle, which ranges from 10 days to 100 days, depending upon the half-life of the isotope product.

1.1 Four Isotope Products Requested by the NERAC Subcommittee

Iodine-131

Iodine-131 ($t_{1/2}$ = 8.0 days) is produced by irradiation of tellurium-130 targets in a hydrided rapid radioisotope retrieval (R3) assembly for 25 days. The iodine-131 product is separated from the tellurium target material by a dry distillation procedure (~400-500 °C in a tubular apparatus evacuated to ~10^{-5} mm) with cryogenic trapping of the iodine gas. The product is analyzed by inductively coupled plasma atomic emission spectroscopy (ICP-AES) for chemical purity, and by gamma energy analysis (GEA) for nuclide content.

Table 1 summarizes the production cost per cycle for production of iodine-131. The product yield at the end of the 25-day cycle is 260 curies, with a production cost of $1.02 per millicurie. This cost compares favorably with the current market prices for radiochemically pure iodine-131, which range from $1.50 to $15.00 per millicurie (depending upon the supplier).

As an example of the activity-based cost analysis that is the basis for the cumulative costs shown in Table 1, the cost estimates for target fabrication, testing and qualification, and insertion and retrieval at FFTF are shown in Table 2. The irradiation charge shown in Table 1 is based on the FFTF business model that is described in detail in the FFTF Scoping Plan (PNNL 1999b).

Table 3 provides details for iodine-131 on the activity-based costing of the target processing, product packaging, and transport to the express mail carrier at a local airport.

Table 1. Summary of Costs for Production at FFTF of Iodine-131

Estimated Budget		I-131		
Activity[a]	Estimate 10 Cycles Per Year	FY99 Estimate Per Cycle	Units Produced (mCi Per Cycle)	Production Cost Per Unit ($/mCi)[b]
Fabrication of Targets (ST0101010)	$758,000	$75,800	260,000	$0.29
Irradiation of Targets (ST0101020)	$1,557,000	$155,700	260,000	$0.60
Chemical Processing (ST0101040)	$60,000	$6,000	260,000	$0.02
Waste Management (ST0101050)	$38,000	$3,800	260,000	$0.01
Quality Assurance (ST0101060)	$77,000	$7,700	260,000	$0.03
ES&H, Regulatory Compliance & Safety (ST0101070)	$13,500	$1,350	260,000	$0.01
Product Packaging (ST0101080)	$22,000	$2,200	260,000	$0.01
Program Management (ST0101090)	$120,500	$12,050	260,000	$0.05
Production Total (ST01)	**$2,646,000**	**$264,600**	**260,000**	**$1.02**
Customer Sales & Service @ 8% of Processing Cost	$15,000	$1,500		
I-131 GRAND TOTAL		**$266,100**		

(a) Shipments are sent FOB Hanford
(b) Based on number of curies at production.

Table 2. Target Fabrication and Testing Costs for Iodine-131

	Target Fabrication at FFTF		Target Testing		Target Insert and Retrieval		Ship to RPL	
	Hrs	Cost	Hrs	Cost	Hrs	Cost	Hrs	Cost
Project Manager	73	$7,260	37	$3,740	2	$200		
Scientist	143	$12,870	77	$6,930	4	$360		
Technician	270	$18,900	133	$9,310	56	$3,920		
On-Site Transport							4	$1,060
Sub-Total Burdened Labor	**486**	**$39,030**	**247**	**$19,980**	**62**	**$4,480**	**4**	**$1,060**
Material 1 Supplies		$5,900						
Material 2 Equipment		$2,950						
Sub-Total		$8,850						
Sub-Total Burdened Material		**$8,850**		**$0**		**$0**		**$0**
Subcontract: On-Site Transportation							2	$530
% Burden Factor								
Sub-Total Burdened Subcontracts		**$0**		**$0**		**$0**	**2**	**$530**
Other: Rad Waste Disposal		$3,000						
Sub-Total Other		**$3,000**		**$0**		**$0**		**$0**
Task Total	**486**	**$50,880**	**247**	**$19,980**	**62**	**$4,480**	**4**	**$1,590**

ST01 FTE Hours	**799**	
ST01 Burdened FTE Cost		**$64,550**
ST01 Burdened Material		**$8,850**
ST01 Subcontract Cost		**$530**
ST01 Other Cost		**$3,000**
ST01 I-131 Targetry Cost		**$76,930**
Value Recovery & Added Cost Multipliers	16%	**$12,300**
GRAND TOTAL		**$89,230**

Table 3. Radiochemical Processing, Packaging, and Shipping Costs for Iodine-131

	Preparation and Receiving		Process Target		Analytical and QA/QC		Package and Ship Product	
	Hrs	Cost	Hrs	Cost	Hrs	Cost	Hrs	Cost
Technical Specialist A	4	$350						
Manager A	3	$530						
Manager B	2	$300						
Scientist	2	$250	7	$875			1	$125
Technician A	6	$630	24	$2,520			1	$105
Technician B	4	$420			6	$630	3	$315
Technical Specialist B							1	$95
On-site Transport							2	$530
Radiation Specialist	4	$420	8	$840			1	$105
Analytical					4	$6,965		
QA Specialist					1	$105		
Sub-Total Burdened Labor	**25**	**$2,900**	**39**	**$4,235**	**11**	**$7,700**	**9**	**$1,275**
Material 1 Packaging Material								$200
Material 2 Supplies & Chemicals				$700				
Sub-Total Unburdened Material				$700				$200
% Burden Factor 19.4%				$135				$40
Sub-Total Burdened Material		**$0**		**$835**		**$0**		**$240**
Subcontract: On-Site Transportation				$265				$550
% Burden Factor 19.4%				$50				$105
Sub-Total Burdened Subcontracts		**$0**		**$315**		**$0**		**$655**
Other: Rad Waste Disposal			3	$800				
Sub-Total Other		**$0**	**3**	**$800**		**$0**		**$0**
Task Total	**25**	**$2,900**	**42**	**$6,185**	**11**	**$7,700**	**9**	**$2,170**

ST01 FTE Hours	**87**	
ST01 Burdened FTE Cost		**$16,110**
ST01 Burdened Material		**$1,075**
ST01 Subcontract Cost		**$970**
ST01 Other Cost		**$800**
ST01 I-131 Processing Cost		**$18,955**
Customer Sales & Service @ 8%		**$1,500**
GRAND TOTAL		**$20,455**

Iodine-125

Iodine-125 ($t_{1/2}$ = 60.1 days) will be produced by irradiation of xenon-124 gas in a gas loop assembly for 100 days. The target gas is transmuted to xenon-125 ($t_{1/2}$ = 17.1 hr), which then decays to the iodine-125 product that is cryogenically trapped. The inert xenon target gas and the krypton gas used to push xenon through the gas line are distilled off, and the iodine-125 product is removed chemically from the wall of the cryotrap. The product is then analyzed for chemical purity and radionuclide content. The production costs for 43.3 curies of iodine-125 are shown in Table 4. The unit production cost is $14.63 per millicurie, which is within the range of market prices of $8 to $20 per millicurie for iodine-125.

Palladium-103

Palladium-103 ($t_{1/2}$ = 17.0 days) will be produced by irradiation of palladium-102 in a hydrided R3 assembly for 25 days. Following irradiation, the target material will be dissolved in nitric acid or aqua regia, evaporated to dryness, brought back into solution with the acid selected by the customer, and analyzed for chemical purity and radionuclide content. No separation will be made of the palladium-102 target material and the palladium-103 product. The production costs for 48 curies of palladium-103 are shown in Table 6. The unit production cost is $7.46 per millicurie, which is slightly below the market price of $9 to $12 per millicurie.

Table 4. Summary of Costs for Production at FFTF of Iodine-125

Estimated Budget		I-125		
Activity[a]	**Estimate 3 Cycles Per Year**	**FY99 Estimate Per Cycle**	**Units Produced (mCi Per Cycle)**	**Production Cost Per Unit ($/mCi)[b]**
Fabrication of Targets (ST0101010)	$238,800	$79,600	43,330	$1.84
Irradiation of Targets (ST0101020)	$1,556,100	$518,700	43,330	$11.97
Chemical Processing (ST0101040)	$23,550	$7,850	43,330	$0.18
Waste Management (ST0101050)	$10,500	$3,500	43,330	$0.08
Quality Assurance (ST0101060)	$23,100	$7,700	43,330	$0.18
ES&H, Regulatory Compliance & Safety (ST0101070)	$4,050	$1,350	43,330	$0.03
Product Packaging (ST0101080)	$6,600	$2,200	43,330	$0.05
Program Management (ST0101090)	$38,850	$12,950	43,330	$0.30
Production Total (ST01)	**$1,901,550**	**$633,850**	**43,330**	**$14.63**
Customer Sales & Service @ 8% of Processing Cost	$5,100	$1,700		
I-125 GRAND TOTAL		**$635,550**		

(a) Shipments are sent FOB Hanford.
(b) Based on number of curies at production.

Table 5. Summary of Costs for Production at FFTF of Palladium-103

Estimated Budget		Pd-103		
Activity[a]	Estimate 10 Cycles Per Year	FY99 Estimate Per Cycle	Units Produced (mCi Per Cycle)	Production Cost Per Unit ($/mCi) [b]
Fabrication of Targets (ST0101010)	$3,218,000	$321,800	48,000	$6.70
Irradiation of Targets (ST0101020)	$62,500	$6,250	48,000	$0.13
Chemical Processing (ST0101040)	$41,000	$4,100	48,000	$0.09
Waste Management (ST0101050)	$35,000	$3,500	48,000	$0.07
Quality Assurance (ST0101060)	$77,000	$7,700	48,000	$0.16
ES&H, Regulatory Compliance & Safety (ST0101070)	$7,250	$725	48,000	$0.02
Product Packaging (ST0101080)	$22,000	$2,200	48,000	$0.05
Program Management (ST0101090)	$120,250	$12,025	48,000	$0.25
Production Total (ST01)	**$3,583,000**	**$358,300**	**48,000**	**$7.46**
Customer Sales & Service @ 8% of Processing Cost	$13,000	$1,300		
Pd-103 GRAND TOTAL		**$359,600**		

(a) Shipments are sent FOB Hanford.
(b) Based on number of curies at production.

Table 6. Summary of Costs for Production at FFTF of Phosphorus-32

Estimated Budget		P-32		
Activity[a]	Estimate 10 Cycles Per Year	FY99 Estimate Per Cycle	Units Produced (mCi Per Cycle)	Production Cost Per Unit ($/mCi)[b]
Fabrication of Targets (ST0101010)	$40,500	$4,050	700	$5.79
Irradiation of Targets (ST0101020)	$31,000	$3,100	700	$4.43
Chemical Processing (ST0101040)	$39,000	$3,900	700	$5.57
Waste Management (ST0101050)	$35,000	$3,500	700	$5.00
Quality Assurance (ST0101060)	$77,000	$7,700	700	$11.00
ES&H, Regulatory Compliance & Safety (ST0101070)	$9,500	$950	700	$1.36
Product Packaging (ST0101080)	$22,000	$2,200	700	$3.14
Program Management (ST0101090)	$14,500	$1,450	700	$2.07
Production Total (ST01)	**$268,500**	**$26,850**	**700**	**$38.36**
Customer Sales & Service @ 8% of Processing Cost	$15,000	$1,500		
P-32 GRAND TOTAL		**$28,350**		

(a) Shipments are sent FOB Hanford.
(b) Based on number of curies at production.

Phosphorus-32

Phosphorus-32 ($t_{1/2}$ = 14.3 days) is produced by irradiation of a sulfur-32 target in an R3 assembly for 25 days. The product isotope is separated from the sulfur target material by dissolving the target in carbon disulfide and passing the solution through an activated carbon column. The column is then eluted with carbon disulfide to desorb the sulfur, dried, and eluted with warm (75 °C) nitric acid (5 M) to recover the phosphorus-32 product. The product is analyzed for chemical and nuclide purity. The production costs for 700 millicuries of phosphorus-32 are shown in Table 6. The unit production cost is $38.36 per millicurie, which is within the range of market prices of $25 to $85 per millicurie of phosphorus-32.

1.2 Other Examples of Research Isotopes

In this section of the report, cost analyses are presented for the production at FFTF of six isotopes that are of interest for cancer therapy (e.g., copper-67, rhenium-186 and rhenium-188 derived from a tungsten-188 generator), bone pain palliation in patients with advanced metastatic bone cancer (e.g., strontium-89 and tin-117m), and for calibration of gamma imaging systems (gadolinium-153).

Copper-67

Copper-67 ($t_{1/2}$ = 2.58 days) is produced by irradiating a zinc-67 oxide target in an R3 assembly for 10 days. Following irradiation, the zinc oxide is dissolved in sulfuric acid, which is then placed in an electrochemical cell and the copper-67 deposited on a platinum electrode. After 30 min. the solution containing zinc is removed and replaced with fresh acid solution, after which the copper deposition on the platinum electrode is continued for another 30 min. This procedure is repeated twice to ensure a high purity of the deposited copper-67. The platinum electrode is then removed and the deposited copper is dissolved by immersing the electrode in concentrated nitric acid. This solution is evaporated to dryness and the copper-67 product is then dissolved in an acid solution specified by the customer. The final product is analyzed for chemical purity and radionuclide content. The production costs for 1.85 curies of copper-67 are shown in Table 7. The unit production cost is $55.16 per millicurie, which compares favorably with the market price of $93 per millicurie.

Gadolinium-153

Gadolinium-153 ($t_{1/2}$ = 242 days) is produced by irradiation of natural europium-151/153 oxide pellets in a long-irradiation vehicle (LIV) for 100 days. Following irradiation, the target material is dissolved in acetic acid and the solution is contacted with granular zinc metal in an inert argon atmosphere to convert the europium (III) to europium (II). A sulfate salt is then added to precipitate the europium (II), thereby separating it from the gadolinium-153 product. This procedure is repeated three times, at which point the gadolinium-153 has the 99.999% level of purity required for its use as a calibration isotope. The purified gadolinium-153 is then subjected to oxalate precipitation,

Table 7. Summary of Costs for Production at FFTF of Copper-67

Estimated Budget		Cu-67		
Activity[a]	Estimate 25 Cycles Per Year	FY99 Estimate Per Cycle	Units Produced (mCi Per Cycle)	Production Cost Per Unit ($/mCi)[b]
Fabrication of Targets (ST0101010)	$982,500	$39,300	1850	$21.24
Irradiation of Targets (ST0101020)	$777,500	$31,100	1850	$16.81
Chemical Processing (ST0101040)	$230,000	$9,200	1850	$4.97
Waste Management (ST0101050)	$87,500	$3,500	1850	$1.89
Quality Assurance (ST0101060)	$192,500	$7,700	1850	$4.16
ES&H, Regulatory Compliance & Safety (ST0101070)	$33,750	$1,365	1850	$0.73
Product Packaging (ST0101080)	$55,000	$2,200	1850	$1.19
Program Management (ST0101090)	$192,500	$7,700	1850	$4.16
Production Total (ST01)	**$2,551,250**	**$102,050**	**1850**	**$55.16**
Customer Sales & Service @ 8% of Processing Cost	$31,250	$1,250		
Cu-67 GRAND TOTAL		**$103,300**		

(a) Shipments are sent FOB Hanford.
(b) Based on number of curies at production.

followed by filtration and calcination to gadolinium oxide. These procedures are the subject of a U.S. patent application filed in August 1998. The final product is analyzed for chemical purity and radionuclide content. The production costs for 66 curies of gadolinium-153 are shown in Table 8. The unit production cost is $1.04 per millicurie, which compares favorably with the market price of $3.00 per millicurie.

Rhenium-186

Rhenium-186 ($t_{1/2}$ = 3.78 days) is produced by irradiation of rhenium-185 in a hydrided R3 assembly for 25 days. Following irradiation, the target material is dissolved in nitric acid or aqua regia, evaporated to dryness, and redissolved in an acid specified by the customer. No effort is made to separate the rhenium-185 target material from the rhenium-186 product. The final product is analyzed for chemical purity and radionuclide content. The production costs for 15 curies of rhenium-186 are shown in Table 9. The unit production cost is $1.43 per millicurie, which compares favorably with the market price of $7.00 per millicurie.

Tin-117m

Tin-117m ($t_{1/2}$ = 13.6 days) is produced by the irradiation of tin-116 in a hydrided R3 assembly for 25 days. Following irradiation, the target material is dissolved in nitric acid or aqua regia, evaporated to dryness, and redissolved in an acid specified by the customer. No effort is made to separate the tin-116 target material from the tin-117m product. The product is analyzed for chemical purity and radionuclide content. The production costs for 1 curie of tin-117m are shown in Table 10. The unit production cost is $29.75 per millicurie.

Table 8. Summary of Costs for Production at FFTF of Gadolinium-153

Estimated Budget		Gd-153		
Activity[a]	**Estimate 3 Cycles Per Year**	**FY99 Estimate Per Cycle**	**Units Produced (mCi Per Cycle)**	**Production Cost Per Unit ($/mCi)[b]**
Fabrication of Targets (ST0101010)	$27,000	$9,000	66,000	$0.14
Irradiation of Targets (ST0101020)	$93,000	$31,000	66,000	$0.47
Chemical Processing (ST0101040)	$32,700	$10,900	66,000	$0.17
Waste Management (ST0101050)	$10,500	$3,500	66,000	$0.05
Quality Assurance (ST0101060)	$23,100	$7,700	66,000	$0.12
ES&H, Regulatory Compliance & Safety (ST0101070)	$4,500	$1,500	66,000	$0.02
Product Packaging (ST0101080)	$6,600	$2,200	66,000	$0.03
Program Management (ST0101090)	$9,300	$3,100	66,000	$0.05
Production Total (ST01)	**$206,700**	**$68,900**	**66,000**	**$1.04**
Customer Sales & Service @ 8% of Processing Cost	$6,000	$2,000		
GD-153 GRAND TOTAL		**$70,900**		

(a) Shipments are sent FOB Hanford.
(b) Based on number of curies at production.

Table 9. Summary of Costs for Production at FFTF of Rhenium-186

Estimated Budget		Re-186		
Activity[a]	**Estimate 10 Cycles Per Year**	**FY99 Estimate Per Cycle**	**Units Produced (mCi Per Cycle)**	**Production Cost Per Unit ($/mCi)[b]**
Fabrication of Targets (ST0101010)	$29,500	$2,950	15,000	$0.20
Irradiation of Targets (ST0101020)	$7,750	$775	15,000	$0.05
Chemical Processing (ST0101040)	$26,750	$2,675	15,000	$0.18
Waste Management (ST0101050)	$35,000	$3,500	15,000	$0.23
Quality Assurance (ST0101060)	$77,000	$7,700	15,000	$0.51
ES&H, Regulatory Compliance & Safety (ST0101070)	$7,500	$750	15,000	$0.05
Product Packaging (ST0101080)	$22,000	$2,200	15,000	$0.15
Program Management (ST0101090)	$9,500	$950	15,000	$0.06
Production Total (ST01)	**$215,000**	**$21,500**	**15,000**	**$1.43**
Customer Sales & Service @ 8% of Processing Cost	$13,000	$1,300		
Re-186 GRAND TOTAL		**$22,800**		

(a) Shipments are sent FOB Hanford.
(b) Based on number of curies at production.

Table 10. Summary of Costs for Production at FFTF of Tin-117m

Estimated Budget			Sn-117m	
Activity[a]	Estimate 10 Cycles Per Year	FY99 Estimate Per Cycle	Units Produced (mCi Per Cycle)	Production Cost Per Unit ($/mCi)[b]
Fabrication of Targets (ST0101010)	$67,750	$6,775	1000	$6.78
Irradiation of Targets (ST0101020)	$35,000	$3,500	1000	$3.50
Chemical Processing (ST0101040)	$38,750	$3,875	1000	$3.88
Waste Management (ST0101050)	$35,000	$3,500	1000	$3.50
Quality Assurance (ST0101060)	$77,000	$7,700	1000	$7.70
ES&H, Regulatory Compliance & Safety (ST0101070)	$7,500	$750	1000	$0.75
Product Packaging (ST0101080)	$22,000	$2,200	1000	$2.20
Program Management (ST0101090)	$14,500	$1,450	1000	$1.45
Production Total (ST01)	**$297,500**	**$29,750**	**1000**	**$29.75**
Customer Sales & Service @ 8% of Processing Cost	$12,500	$1,250		
Sn-117m GRAND TOTAL		**$31,000**		

(a) Shipments are sent FOB Hanford.
(b) Based on number of curies at production.

Strontium-89

Strontium-89 ($t_{1/2}$ = 50.5 days) is produced by irradiation of strontium-88 carbonate in a hydrided LIV assembly for 100 days. The strontium-89 is purified to remove traces of contaminants using a strontium-selective chromatographic resin (Sr-Spec). The column is rinsed with 3 M nitric acid to remove all elements other than strontium, and the strontium is then eluted with 0.3 M nitric acid. The final product is evaporated to dryness and then dissolved in an acid specified by the customer. No effort is made to separate the strontium-89 from other species of strontium contained in the final product. The final product is analyzed for chemical purity and radionuclide content. The production costs for 4.2 curies of strontium-89 are shown in Table 11. The unit production cost is $10.83 per millicurie, which compares favorably with the market price of $113 per millicurie.

Tungsten-188

Tungsten-188 ($t_{1/2}$ = 69.4 days) is produced by irradiation of tungsten 186 in a hydrided LIV assembly for 100 days. The primary use of the tungsten-188 is as a generator material for the rhenium-188 decay product. The target is dissolved in nitric acid or aqua regia, evaporated to dryness, and redissolved in an acid specified by the customer. No effort is made to separate the tungsten-186 target from the tungsten-188 product. The final product is analyzed for chemical purity and radionuclide content. The production costs for 11 curies of tungsten-188 are shown in Table 12. The unit production cost is $12.86 per millicurie, which is higher than the current market price of $4 to $5 per millicurie.

Table 11. Summary of Costs for Production at FFTF of Strontium-89

Estimated Budget		Sr-89		
Activity[a]	**Estimate 3 Cycles Per Year**	**FY99 Estimate Per Cycle**	**Units Produced (mCi Per Cycle)**	**Production Cost Per Unit ($/mCi)**[b]
Fabrication of Targets (ST0101010)	$21,000	$7,000	4200	$1.67
Irradiation of Targets (ST0101020)	$46,500	$15,500	4200	$3.69
Chemical Processing (ST0101040)	$17,700	$5,900	4200	$1.40
Waste Management (ST0101050)	$10,500	$3,500	4200	$0.83
Quality Assurance (ST0101060)	$23,100	$7,700	4200	$1.83
ES&H, Regulatory Compliance & Safety (ST0101070)	$6,600	$2,200	4200	$0.52
Product Packaging (ST0101080)	$6,600	$2,200	4200	$0.52
Program Management (ST0101090)	$4,500	$1,500	4200	$0.36
Production Total (ST01)	**$136,500**	**$45,500**	**4200**	**$10.83**
Customer Sales & Service @ 8% of Processing Cost	$4,350	$1,450		
Sr-89 GRAND TOTAL		**$46,950**		

(a) Shipments are sent FOB Hanford.
(b) Based on number of curies at production.

Table 12. Summary of Costs for Production at FFTF of Tungsten-188

Estimated Budget		W-188		
Activity[a]	**Estimate 3 Cycles Per Year**	**FY99 Estimate Per Cycle**	**Units Produced (mCi Per Cycle)**	**Production Cost Per Unit ($/mCi)**[b]
Fabrication of Targets (ST0101010)	$352,800	$117,600	11,000	$10.69
Irradiation of Targets (ST0101020)	$2,700	$900	11,000	$0.08
Chemical Processing (ST0101040)	$16,800	$5,600	11,000	$0.51
Waste Management (ST0101050)	$10,500	$3,500	11,000	$0.32
Quality Assurance (ST0101060)	$23,100	$7,700	11,000	$0.70
ES&H, Regulatory Compliance & Safety (ST0101070)	$2,850	$950	11,000	$0.09
Product Packaging (ST0101080)	$6,600	$2,200	11,000	$0.20
Program Management (ST0101090)	$9,000	$3,000	11,000	$0.27
Production Total (ST01)	**$424,350**	**$141,450**	**11,000**	**$12.86**
Customer Sales & Service @ 8% of Processing Cost	$4,350	$1,450		
W-188 Grand Total		**$142,900**		

(a) Shipments are sent FOB Hanford.
(b) Based on number of curies at production.

2.0 What process, mechanism, and organizational structure do you have for the timely distribution of the produced product?

Response:

Packaging and distribution of isotope products are directly coupled to the isotope production process. Upon preparation of a vial of isotope to the specifications provided by a customer, the vial is transferred into a lead container (pig) with an overpack and taken to an adjacent laboratory. A member of the PNNL isotope production team then packages the pig into a labeled, DOT-approved container and inserts customer-specific data. An offsite Radioactive Shipment Record and other paperwork required by the Department of Transportation are attached to the drum and it is taken to the Richland airport (a distance of about 2 miles) for shipment by Airborne Express to the customer. In addition to Airborne Express, other major express mail carriers such as Federal Express have offices at the three airports located within a 15-mile radius of the Hanford Site, and are used for shipping of isotopes to some international locations. The overall time that elapses between preparation of the customer vial and its delivery to the express mail carrier is typically 2 to 4 hours.

A detailed flowchart showing all of the activities involved in the packaging and shipping of an isotope product is presented in PNNL (1999a) (Section 2.6.1). PNNL has contracts with two subcontractors that assist with the shipping of isotopes: (1) DynCorp transports isotope samples from the production laboratory at the RPL to the 222S Building for ICP analysis, and (2) Waste Management Federal Services transports the isotope shipping containers from the RPL to the airport for delivery to the express mail carrier. All containers that are sent to customers contain A-type quantities of isotopes to minimize shielding requirements and avoid delays in isotope delivery. Shipments are made FOB Hanford, and the customer pays the costs of express mail shipping. In general, the record of Airborne Express and other carriers has been very good, with an average on-time delivery record of 98% for more than 1200 shipments over the past two years.

3.0 What process, mechanism, and organizational structure do you have for customer service?

Response:

The customer sales and service functions are conducted as part of the Hanford Radioisotopes Program at a total level of effort of 1.5 FTE. Customer orders are taken by telephone, E-mail, or FAX and compiled into a spreadsheet that forms the basis for the weekly isotope production campaign. Care is taken to note all customer-specific ordering information, and to compile all of the necessary paperwork such as a copy of the customer's radioactive materials license in advance of shipping (to ensure that the customer can receive the shipment). The sales and service staff also work with PNNL and Waste Management Federal Services transportation specialists to identify the most efficient shipping routes and air carriers for international orders (about 50% of the total isotope sales in 1997-1999). Special efforts are made to accommodate special requests, especially when the isotope is required for the treatment of critically ill cancer patients. The response time under those circumstances can be as little as a few hours. Approximately 350 special requests have been met successfully over the past 10 years.

If FFTF undertakes isotope production in 2004, it is expected that the customer sales and service functions will be increased at that time to a level of effort of approximately 5.5 FTE. In addition, opportunities for privatization of this component of the isotopes program are being explored through ongoing discussions with commercial companies.

4.0 Will you sign contracts that guarantee delivery at the contracted time of delivery, and where the contract has penalty clauses for untimely delivery of the specified product?

Response:

PNNL supplies isotopes under a standard DOE customer service agreement, and handles invoicing and all other aspects of each sales transaction. All isotope products are shipped FOB Hanford, and become the responsibility of the customer at the time of shipment. Accordingly, our service contracts do not have penalty clauses for untimely delivery by the express mail carrier. However, in practice we have routinely waived all charges if the delivery of an isotope product is delayed and the customer is unable to use it. This waiver of charges is subject to DOE approval, but the Isotope Programs Office (NE-70) staff have consistently permitted a waiver to be made under reasonable circumstances. In our opinion, this practice is more "customer friendly" than introducing a penalty clause for untimely delivery in the customer service contract.

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